FACULTY OF BIOSCIENCE ENGINEERING

# Implementing realistic biological variability in an individual-based Dynamic Energy Budget model

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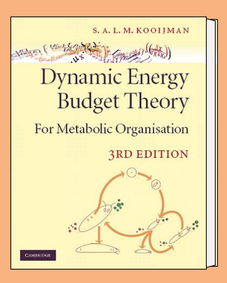
## Introduction

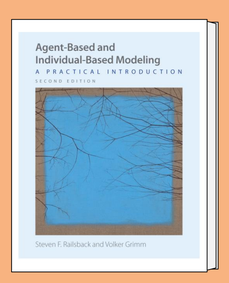
### DEB-IBM

- Allows for extrapolation of individual-level energetic effects to populations




DEB[1]

+




IBM[2]

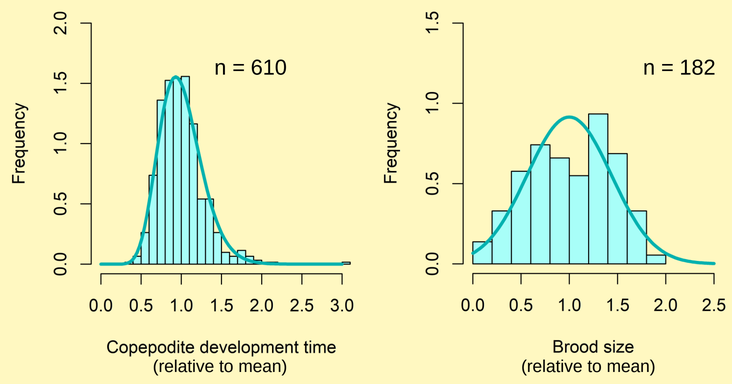
### Species: *Nitocra spinipes*

- Brackish water copepod
- Worldwide distribution
- Ecotoxicological test species*
- DEB parameters available[3]

* - OECD ENV/JM/MONO(2014)17
- ISO 14669:1999
- ISO/TS 18220:2016

### Inter-individual variability

- Integral in population resilience
- Data available for *N. spinipes*:

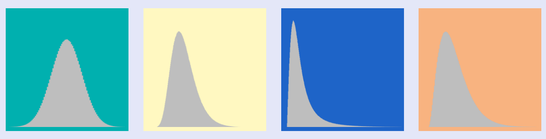



**Challenge: How can variability in DEB parameters be estimated from variation in data?**

### What parameters?

$\{\dot{F}_m\}$ $\kappa_X$ $[E_G]$ $\kappa$ $\dot{k}_J$
$\{\dot{p}_{Am}\}$ $[\dot{p}_M]$ $\dot{v}$ $\{\dot{p}_T\}$ $E_H^p$
$\kappa_R$ $E_H^b$ $E_H^j$

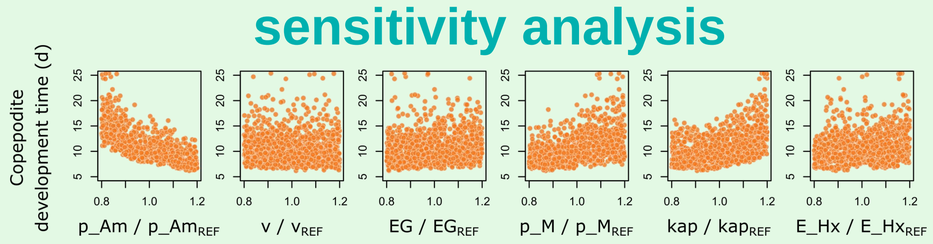
### What probability distributions?



### What scale of variation?

## Methods

### Variance based global sensitivity analysis




Monte Carlo simulations with all parameters uniformly distributed (+/- 20%) around their respective reference value from the preceding parameter estimation[3]

$$S_i = \frac{V_{X_i}\left(E_{X_{\sim i}}(Y|X_i)\right)}{V(Y)}$$

The first-order effect indices $S_i$[4] (always between 0 and 1) indicate how much of the output variance $V(Y)$ can be directly attributed to each respective input parameter $X_i$

### Compare common distribution types

**Gaussian**

vs.

**Log-normal**

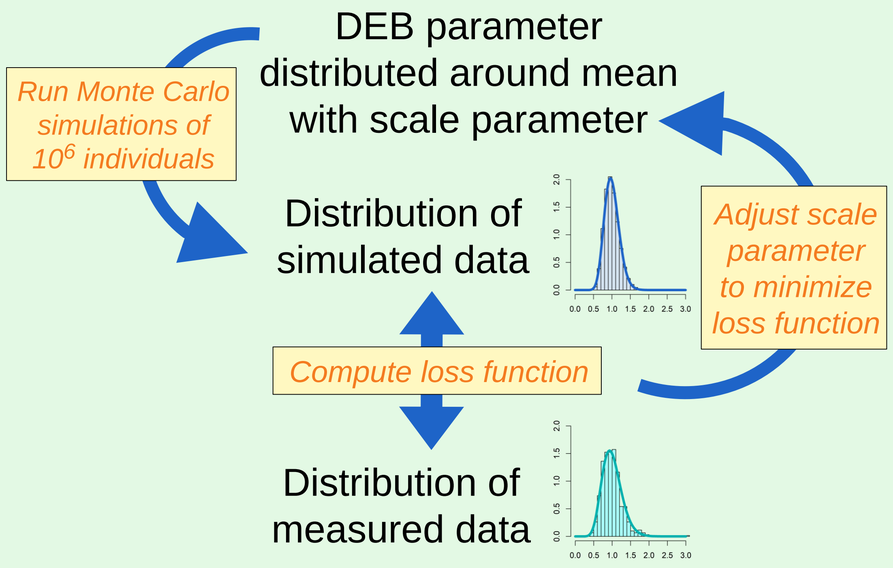
vs.

**Log-logistic**

vs.

**Gamma**

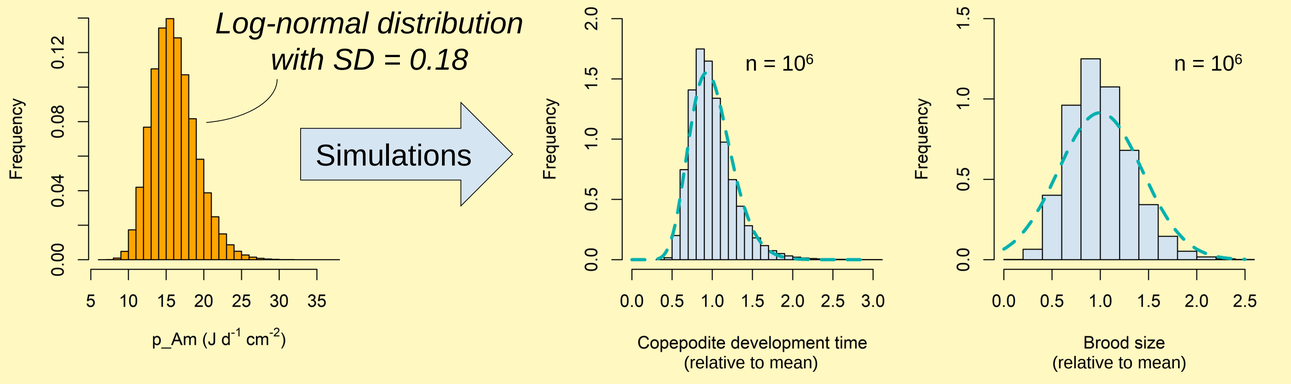
### Optimisation algorithm for scale parameter




## Results & Discussion

| Parameter | $\{\dot{p}_{Am}\}$ | $\dot{v}$ | $[E_G]$ | $[\dot{p}_M]$ | $\kappa$ | $E_H^x$ |
|---|---|---|---|---|---|---|
| $S_i$ Dev. time | 0.44 | 0.003 | 0.03 | 0.06 | 0.36 | 0.06 |
| $S_i$ Brood size | 0.42 | 0.001 | 0.01 | 0.11 | 0.39 | 0.05 |

- Observed endpoints are most sensitive to the maximum assimilation rate $\{\dot{p}_{Am}\}$
- Drawing $\{\dot{p}_{Am}\}$ from a log-normal distribution with an optimised scale parameter (SD) led to the best possible approximation of the variation in real data




## Conclusions

- Variability in DEB parameters can be estimated from experimental data
- Adding variability to a single parameter provided a good approximation of observed variation in measured data and can easily be implemented in the IBM

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References

[1] Kooijman, S.A.L.M., *Dynamic Energy Budget Theory For Metabolic Organisation*. 3rd ed. 2010, Cambridge: Cambridge University Press
[2] Railsback, S.F. and V. Grimm, *Agent-based and Individual-based Modeling: A Practical Introduction*. 2nd ed. 2019, New Jersey: Princeton University Press
[3] Koch, J. and K.A.C. De Schamphelaere, *Two Dynamic Energy Budget Models for the Harpacticoid Copepod Nitocra spinipes.* Journal of Sea Research, 2018
[4] Saltelli, A., et al., *Variance Based Sensitivity Analysis of Model Output. Design and Estimator for the Total Sensitivity Index*. Computer Physics Communications, 2010. 181(2): p. 259-270

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